Instructions: Answer the following questions to the best of your ability. *Please show your work, and briefly explain your reasoning as necessary. Correct answers with no work/justification will not receive full credit.*

If you cannot answer a questions completely, write down, succinctly, the ideas you have for approaching the problem. Please write clearly.

1. Let $U, V$ be random variables with finite second moment, and let $SD(\cdot)$ denote the usual standard deviation. Find an inequality relating $|SD(U) - SD(V)|$ and $SD(U - V)$.

2. Let $X$ be a random variable with a CDF $F(\cdot)$ that is strictly increasing, and therefore invertible. What is the distribution of $F(X)$?

3. Define what it means for a family $\mathcal{P}$ of densities to be a scale family.

4. Define the notion of a pivot in the theory of confidence sets.

5. Let $U_1, \ldots, U_n$ be an i.i.d. sample from a density $f$ in a scale family $\mathcal{P}$. Describe three essentially different pivots for this situation.


7. Let $X_1, \ldots, X_n$ be i.i.d. $\mathcal{N}(\theta, \sigma^2)$, where $\sigma^2 > 0$ is known.
   a. Find the likelihood ratio tests of $H_0 : \theta = \theta_0$ versus $H_1 : \theta \neq \theta_0$, and express the test in a simple form. You may find it convenient to use the identity $\sum_{i=1}^{n}(u_i - v)^2 = \sum_{i=1}^{n}(u_i - \bar{u})^2 + n(\bar{u} - v)^2$.
   b. Invert the test in part (a) to find a $1 - \alpha$ confidence interval for $\theta$.
   c. Is the test in part (a) unbiased? Justify your answer.
8. Let $X_1, \ldots, X_n$ be i.i.d. random variables taking values in $[0, 1]$ and such that $E X_i = 1/2$. We are interested in upper bounds on the probability

$$\mathbb{P}\left( \frac{X_1}{X_1 + \cdots + X_n} \geq \frac{t}{n} \right)$$

for values of $t > 1$.

a. Find the expected value of $X_1/(X_1 + \cdots + X_n)$. (No extensive calculations are necessary.)

b. Find an upper bound on the probability in (1) using the Bounded Difference (McDiarmid) inequality. Show your work.

c. Find a better bound on the probability in (1).

9. Let $Y \sim \mathcal{N}(0, \Sigma)$ be a multi-normal random vector with covariance matrix $\Sigma$. Suppose that $E Y_i^2 = 1$ for $1 \leq i \leq n$ and that every entry of $\Sigma - I$ is non-negative, where $I$ denotes the $n \times n$ identity matrix. Let $\Phi(\cdot)$ be the CDF of the standard normal. Show that

$$E(\Phi(Y_1) \cdots \Phi(Y_n)) \geq 2^{-n}.$$